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Energy and reliability improvement at large low temperature refrigeration plant

BOC has introduced revolutionary technology to the refrigeration industry that has proven to significantly improve performance when applied to large refrigeration systems. To demonstrate the significance of these new capabilities, BOC has optimised the refrigeration system of a nitrogen liquefaction unit at one of its largest production sites in the UK.

The improvements achieved:

• **Efficiency:** the unit was found to be operating at only 40% of its design efficiency at 4.6Kw/Tonne (refrigeration). After process optimisation, the unit was brought back to near its design specific power of 1.8kW/te

• **Contaminants:** analytical studies revealed that large quantities of oil, moisture and noncondensables were present within the refrigerant unit. These were substantially reduced by the reclamation process.

• **Inventory:** the system was found to have a 30% undercharge of refrigerant. This was brought back to design levels.

• **Payback:** the return on investment was realised within 6 months

York refrigeration unit on BOC site in south Wales

In June 2004, the BOC Refrigerants team carried out a process optimisation at BOC's production facility in Margam, South Wales. The refrigeration plant they worked on is an integral part of the Nitrogen Liquefaction Unit (NLU) and is designed to cool 381 HCMs (hundred cubic meters) of gaseous nitrogen from 28°C down to – 63°C. Margam is one of BOC's largest production sites in the UK. There are three air separation plants on the site with an installed capacity of 2900 tonnes per day (tpd) of gaseous oxygen, the NLU with an installed capacity of 600 tpd liquid nitrogen, plus argon and hydrogen production facilities.

Analysis of the liquid refrigerant samples indicated an extremely high oil and moisture content. In these types of system, an accumulation of oil with oil contaminants can result in the fouling of evaporator tube surfaces. The evaluation model highlighted a difference in the design and actual heat transfer coefficients across the heat exchangers, which confirmed the suspicion of fouling and a need to clean the refrigerant charge and tube surfaces.

Particulates of iron oxide were also evident during the regular refrigerant sampling. Low oxygen levels indicated incomplete oxidation of iron was taking place, aided by the presence of moisture within the system. The evaluation calculated that the refrigerant was superheated by between 20 and 40°C at two of the evaporator outlets.This would cause capacity losses of at least 10-20%. High discharge temperatures and hence pressures can also lead to high maintenance on the compressors. The evaluation model further indicated that there was liquid carryover to the lowest evaporator which had been a problem identified by the plant operators.

The refrigeration system used to cool the nitrogen within the NLU was running warm by more than 15°C.This was contributing to poor specific power at a significant cost to BOC's operation. Additionally system reliability was poor. The first stage in treating the system was to do a complete evaluation:

System Evaluation

The refrigeration system is a multi-stage low temperature unit with four flooded shell and tube type evaporators using R22 shell side and nitrogen gas tube side.
A patented thermodynamic evaluation model was used to profile the refrigeration unit using design records, plant readings and data information on the heat exchangers. The best available engineering assumptions were made in places where there was insufficient data.

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Liquid and gaseous refrigerant samples were analysed against Air Conditioning and Refrigeration Institute specifications, and the oil quality and content was examined to help identify some of the problems within the system and build up a picture of the system's operating performance.

The evaluation showed the system was operating at 40% of design capacity with a specific power of 4.6kW/te compared to the design of 1.79Kw/te. The operation of the system and the vacuum conditions in the evaporators indicated non-condensables were present in the system. This was confirmed by the gaseous phase refrigerant analysis.

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System Rectification

A plant shutdown was scheduled for the purpose of performing the decontamination.
During the rectification stage, the refrigerant was processed through the decontamination unit from each of the 4 evaporators into the receiver. Refrigerant foaming within the lower chamber of the unit again confirmed high quantities of oil.

The refrigerant was cleaned and continuously recirculated through the system at high velocity, to flush contaminants from the evaporators. BOC's non-condensable purger was then used to remove the high level of non-condensables and specialised super drying vessels were used to remove the moisture within the system. A total of 300 litres of oil and moisture was eventually removed from the system. Calculations now indicated that the system was found to be undercharged with refrigerant by 30%!

Outcome of Process Optimisation

The plant achieved a step-change in system performance, with an improvement in specific power consumption, improved capacity, start-up and reliability. Jim Mercer, Margam's Plant Manager said: ''*The efficiency savings realised at this plant will payback the service work within 6 months. BOC Refrigerants have managed to achieve something that we and other refrigeration contractors have been unable to achieve before wholly through the deployment of this new technology. BOC's Service work has by far outstretched our expectations"*

The BOC Refrigerants services are applicable across a wide range of industrial sectors where refrigeration is a key part of an industrial or commercial process. These services have also been used alongside mechanical refrigeration contractors.

Contact BOC more information on 0800 020800